THE OS OPTICUS OF BIRDS WITH PARTICULAR REFERENCE TO ITS DEVELOPMENT IN THE ENGLISH SPARROW, *PASSER DOMESTICUS* (LINNAEUS)

BY

OTTO WILLIAM TIEMEIER

A. B., University of Kansas, 1937

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AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN ZOOLOGY
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ACKNOWLEDGMENTS

The writer wishes to express his sincere appreciation to Dr. F. B. Adamstone for his critical advice, encouragement, and for the invaluable direction that he has freely granted.

He is deeply appreciative to the many persons who have donated or loaned material and especially thankful to Mr. C. D. Bunker of the University of Kansas Museum, who made the large collections of that institution available for study.

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A scleral bone, partially or completely surrounding the entrance of the optic nerve into the eyeball of birds, was first described about 100 years ago. This bone, known as the os opticus, is situated in the cartilaginous layer of the sclera. It is typically horseshoe-shaped with a nasal and temporal arm joined ventrally by a broad base to complete the formation of the horseshoe. In situ the open part of the horseshoe is directed dorsally and slightly backward. In some species a complete ring may be formed or it may consist of only the broad basal portion. Grossly the os opticus is curved to conform to the curvature of the eyeball. From the fundic aspect a wide trough-like groove is apparent in the base of the optic bone. This groove is completely filled by the ventral fibers of the optic nerve.

A total of 639 os optici were recovered upon examination of 7,029 skeletons, 83 sectioned eyes, and 100 eyes stained with alizarin. Including the reports of several early investigators the optic bone has now been found in 219 avian forms comprising 35 families in 9 orders. Thirty-six new species and subspecies found to possess the os opticus are added to those birds previously reported.

Birds are divided into 3 groups on the basis of whether or not they possess the os opticus. Those families that invariably have the bone are: Falconidae, Trochilidae, Alcedinidae, Picidae, Ramphastidae, Pipridae, Tyrannidae, Alaudidae, Hirundinidae, Corvidae, Paridae, Sittidae, Certhiidae, Troglodytidae, Mimidae, Turdidae, Sylviidae, Muscicapidae, Motacillidae, Bombycillidae, Ptilogonatidae, Laniidae, Sturnidae, Zosteropidae, Vireonidae, Parulidae, Ploceidae, Icteridae,

Thraupidae and Fringillidae. Some species and some individuals of the following families may or may not have the os opticus: Areidae, Accipitriidae, Phasianidae, Columbidae and Psittacidae. Even though skeletons and eyes were available for examination from the following families, the optic bone was not found: Struthionidae, Dromiceiidae, Gaviidae, Colymbidae, Hydrobatidae, Pelecanidae, Sulidae, Phalaropidae, Fregatidae, Threskiornithidae, Phoenicopteridae, Anhimidae, Anatidae, Cathartidae, Pandionidae, Megapodidae, Tetraonidae, Meleagridae, Gruidae, Rallidae, Haematopididae, Charadriidae, Scolopacidae, Recurvirostridae, Phalaropidae, Laridae, Rhynchopidae, Cuculidae, Tytonidae, Strigidae, Caprimulgidae, Micropodidae, Bucerotidae and Cinclidae.

The methods used to obtain specimens were: (1) the cleaning of skeletons by use of the dermestid beetle, *Dermestes vulpinus;* (2) sectioning of a portion or entire eyes in paraffin; and (3) staining the sclera with alizarin red S stain for bone. Most specimens were recovered after the workings of the dermestid beetle but it is felt that the alizarin staining procedure is the best because it is more certain of revealing the bone and shows it in relationship to the other ocular structures.

The os opticus consists of cancellous bone which contains many marrow cavities filled with marrow cells, blood vessels and cells and fat cells. The fat cells predominate during the winter months while the marrow cells are more abundant during the spring and summer months. The marrow cavities undergo striking medullary changes during the egg-laying cycle similar to that described for avian long bones. Endosteal bone is formed during the growth of the ovarian follicles and disappears during calcification of the egg shell.

No comparable bone has been found in any recent vertebrate and probably no truly homologous structure in any fossil form. What is presumably an optic bone from the Devonian arthrodiran, *Dinichthys terelli,* is somewhat similar but only because both bones are from the eye. The os opticus

differs from the anterior sclerotic ring of bones in the following respects: (1) it is formed almost entirely by intracartilaginous ossification; (2) from all observations it forms much later than the ring bones; (3) it almost invariably contains marrow cavities; and (4) it usually consists of a single bone.

From a study of 639 optic bones in approximately 186 species of birds it is the opinion of the writer that the os opticus can not be considered as possessing consistent morphological characteristics which would be of value to the systematist. Although the basic pattern may be the same in all the representatives of a species, the addition of certain elements such as the lateral expansion of the nasal arm to form a foramen for the long ciliary nerve and artery, and ventral expansions of the basal projections to form another foramen for the exit of the united chorioidal and pectineal vein, alter this basic pattern to such an extent that the os optici are hardly recognizable as being from different birds of the same species.

Several functions are suggested for the optic bone. These are: (1) protection of the eye against shock; (2) maintenance of rigidity of the eyeball; (3) protection of the ventral segment of the optic nerve. No experiments could be perceived that would definitely prove any of these functions because it is impractical, if not impossible, to remove the os opticus. It is largest in woodpeckers, crows and jays that obtain their food by pecking but it is also present in hummingbirds and flycatchers that do not peck.

No information was available concerning the time of formation of the os opticus in the English sparrow, so nestling birds were captured and reared to the desired ages. Eyes were taken from these birds, decalcified and sectioned in paraffin. It was observed that a small area of cartilage destruction appears at about the twenty-second day after hatching. The first evidence of the ossification process is proliferation of the mesenchymal cells in the osteoblastic layer of the perichondrium. These cells, along with small

blood vessels, begin to penetrate the cartilage to produce a small marrow bud. At first the cells are undifferentiated but they soon become the osteoblasts and osteoclasts of the marrow bud. The matrix of the cartilage becomes calcified shortly in advance of the invasion of the bud. Subsequently dissolution of the cartilage takes place followed by deposition of bone.

Shortly after the appearance of the first marrow bud numerous other buds form in the same manner and soon involve the entire cartilaginous ring. Most of the os opticus is formed by replacement of this thickened cartilaginous layer of the sclera by bone which surrounds the point of entrance of the optic nerve into the eyeball. A thin band of intramembranous bone is formed on the external surface of the cartilage in the region of the base of the os opticus but this band is fused to the intracartilaginous bone before the bird becomes an adult.

The process of cartilage breakdown and replacement with bone is divided into 7 different stages because in each there are significant changes. The oldest English sparrow reared was 40 days old when sacrified and sections made of the eyes show that the ossification process is nearly complete.

VITA

Otto William Tiemeier was born at Lincolnville, Kansas, on September 20, 1912. He attended the elementary school of that city and was graduated from Lincolnville High School in 1930. His undergraduate education was obtained at the University of Kansas, Lawrence, Kansas, where he received the Bachelor of Arts degree in 1937. The Master of Arts degree was also received from the University of Kansas, Lawrence, Kansas, in 1939. From 1932 to 1939 he was an assistant in the University of Kansas Museum. During the two academic years 1939-1941 he was employed as an assistant in zoology at the University of Illinois, while continuing graduate studies. He received a Fellowship in Zoology for the spring semester of 1946 and the third-year Fellowship for 1946-1947.

From June, 1941, to July, 1942, he was a Junior Biologist with the Soil Conservation Service at Belleville, Illinois. In August, 1942, he accepted a position as Biologist with the Illinois State Natural History Survey at Urbana, Illinois, working on a project under the Pittman-Robertson program. He entered the U. S. Navy in November, 1943, and became a clinical laboratory technician.

The summer of 1946 was spent in study at the Marine Biological Laboratory located at Woods Hole, Massachusetts.

He was elected to Phi Sigma in 1939 and became an associate member of Sigma Xi in 1941 and an active member in 1947. He is an associate member of the American Ornithologists' Union, the Mammalogist's Society, and the Wildlife Society.

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